NATIONAL TRANSPORTATION SAFETY BOARD
Office of Aviation Safety
Washington, D.C. 20594
November 22, 2013

Group Chairman's Factual Report

STRUCTURES

DCA13MA120

ACCIDENT

Location:	San Francisco International Airport (SFO)
Date:	July 6, 2013
Time:	1128 (PDT) Pacific daylight time
Airplane:	Boeing 777-200 series, HL7742

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SUMMARY

On July 6, 2013 at 11:28 am Pacific daylight time, a Boeing 777, registration HL7742, operated by Asiana Airlines as flight 214, struck the seawall short of runway 28L at San Francisco International Airport. The airplane was destroyed by impact forces and fire. Three of the 291 passengers were fatally injured. The flight was a regularly scheduled passenger flight from Incheon International Airport, Seoul, Korea, and was operated under the provisions of 14 Code of Federal Regulations Part 129. Visual meteorological conditions prevailed at the time of the accident.

DETAILS OF THE INVESTIGATION

1.0 Aircraft Description[1]

Registration Number:	HL7742
Airplane Serial Number:	29171
Airplane Manufacturer:	The Boeing Company
Model:	777-28E(ER)
Engine Manufacturer:	Pratt & Whitney
Model:	PW 4090
Airplane Year:	2006
Airworthiness Certificate:	Standard
Approved Operations:	121
Aircraft Type:	Fixed Wing Multi-Engine
Engine Type:	Turbo Fan
Airplane Category:	Transport
Number of Engines:	2
Max. T/O Weight:	630,000 lbs
Total Time:	37,103 hours & 4 minutes as of July 6, 2013
Total Cycles:	5,385 as of July 6, 2013
Type Certificate	T00001SE

2.0 Accident Site/Wreckage Debris

At 11:28 a.m. Asiana flight 214, HL7742, crashed short of runway 28L's threshold[2]. The landing gear and the tail struck the seawall that projects into San Francisco Bay. Both engines and the tail section separated from the aircraft. The main landing gear[3], the first part of the airplane to hit the seawall, separated cleanly from the airplane as per the design. The vertical and both horizontal stabilizers separated from the airplane and were located on the runway between the seawall and the threshold.

The remainder of the fuselage and wings[4] rotated (yawed) counter-clockwise 330 degrees as

[1] reference Attachment 1, Figure 1
[2] reference Attachment 2, Photo 1
[3] reference Attachment 2, Photo 2
[4] reference Attachment 2, Photo 3

it slid westward. Video showed it pivoting about a wing and the nose while sharply inclined to the ground. It came to rest to the left of the runway 28L, 2,400 feet (730 m) from the initial point of impact at the seawall.

3.0 Fire Damage[5]

About a minute after the airplane came to rest, a dark plume of smoke was observed rising from the wreckage. The fire was traced to a ruptured oil tank above the right engine. The leaking oil fell onto the hot engine and ignited. The fire was not fed by jet fuel.

Portions of the fuselage crown structure above the window belt were burned thru from about body station (BS) 358 aft to about BS 1434. The cabin interior from about the cockpit door aft to about BS 1434 above the passenger floor, waterline (WL) 200, was partially consumed by fire.

4.0 Structure

4.1. Fuselage

Seven sections, 41[6], 43[7], 44[8], 45[9], 46[10], 47[11] and 48[12], define the fuselage. Section 41 is comprised of the fuselage structure from body station (BS) 92.5 to BS 655. Section 43 is comprised of the fuselage structure from BS 655 to BS 1035 where sections 44 and 45 begin. Section 44 and 45 are comprised of the fuselage structure from BS 1035 to BS 1434 where section 46 begins. Section 44 includes the monocoque structure above the passenger floor at stringer (S)-27 and section 45 includes the overwing, keel beam and main landing gear wheel well structure. Section 46 is comprised of the fuselage structure from BS 1434 to BS 1832 where section 47 begins. Section 47 is comprised of the fuselage structure from BS 1832 to BS 2150 where section 48 begins. Section 48 is comprised of the fuselage structure from BS 2150 to BS 2570 which includes the aft pressure bulkhead and empennage attachment structure.

The fuselage shell is a semi-monocoque structure with skin, longitudinal stringers and circumferential frames and bulkheads. The fuselage is a complete torque box throughout its length. Cutouts for doors, windows, escape hatches, and other fuselage openings are reinforced by a local framework of frames, sills, and doublers.

The fuselage has four passenger entry doors (PED) on each side of the fuselage and three lower lobe cargo doors on the right side of the fuselage. The entry doors are inward then outward opening plug type doors. The lower lobe large forward cargo door

[5] reference Attachment 2, Photo 3
[6] reference Attachment 1, Figure 2
[7] reference Attachment 1, Figures 2 & 3
[8] reference Attachment 1, Figures 3 &4
[9] reference Attachment 1, Figures 3, 4 & 5
[10] reference Attachment 1, Figure 6
[11] reference Attachment 1, Figure 6
[12] reference Attachment 1, Figures 6 & 7

(LFCD) is an outward opening shear type cargo door. The lower lobe small aft cargo door (SACD) is an outward opening plug type door and the lower lobe bulk cargo door is an inward opening plug type door.

Between body stations (BS) 126 and BS 2150, the fuselage is pressurized. The aft pressure bulkhead located at BS 2150 is spherical in shape. The nose landing gear wheel well runs from BS 180 to BS 332 and the flat fore/aft, top and side panels serve as the pressure boundary. Over the wing, between BS 1035 and BS 1245, the center wing box upper skin panel serves as the lower surface of the pressurized upper lobe and the upper surface of the main landing gear bay between BS 1245 and BS 1434 located at water line (WL) 200, serves as the lower surface of the pressurized upper lobe. The fuselage serves as the primary pressure boundary from BS 126 to BS 2150, except as noted above.

4.1.1. Fuselage Section 41[13] – BS 92 to 655

Section 41 remained intact and attached to section 43. The fuselage structure appeared mostly undamaged forward of BS 382 and along its entire length below the passenger floor at WL 200 from about stringer S-27 left to S-27 right. PED 1 left (L), 1 right (R) and LFCD cutouts had no visible signs of damage. The upper portion of the nose landing gear (NLG) above the drag link remained attached to the nose wheel well (NWW) structure. The NWW and cockpit structures were undamaged. There was extensive fire damage present from PED 1 to BS 655. The passenger floor beams appeared to be intact and remained attached to the fuselage frames. The fuselage structure was fire damaged above WL 200 from about BS 382 to BS 1035 with the crown panel above the window belt mostly missing with more extensive fire damage on the left hand (LH) side of the fuselage. Most passenger windows in the region were missing. The overhead stow bin support structure (ladder, tie rods, frame attach fittings) was consumed by fire.

All of the observed damage was consistent with ground impact and fire. All of the examined fracture surfaces exhibited features consistent with overstress with no evidence of fatigue damage.

4.1.2. Fuselage Section 43[14] – BS 655 to 1035

Section 43 remained intact and attached to sections 44 and 45. The fuselage structure below the passenger floor at WL 200 from about stringer S-27L to about bottom centerline (BCL) was mostly undamaged from about BS 655 to about BS 1014. The structure below the passenger floor at WL 200 from S-27R to about from about BS 930 to about BS 1035 appeared mostly undamaged. The keel panel below S-45L/R had evidence of minor denting and scraping damage consistent with ground contact. The fuselage structure had severe fire damage above WL 200 and the majority of the passenger windows were missing. The PED 2L and 2R cutouts had no visible signs of

[13] reference Attachment 2, Photos 3, 4, 5 & 6
[14] reference Attachment 2, Photos 3, 4, 5 & 6

damage. Vertical skin wrinkles were present on the LH side between BS 909 and BS 972, from the window belt to about the BCL. A longitudinal skin wrinkle existed on the RH side from about BS 825 to BS 951 at stringer 20. The passenger floor beams appeared to be intact and attached to the fuselage frames. The interior surface of PED 2R had no visible fire damage. There was however extensive fire damage from about BS 846 to BS 1035 above the window belt (S-20L) to S-8R. There was also extensive fire damage on RH side from BS 697 to BS 930 below S-27R to BCL which was in close proximity to the location where the No. 2 engine came to rest. The overhead stow bin support structure (ladder, tie rods, frame attach fittings) was consumed by fire.

All of the observed damage was consistent with ground impact and fire. All of the examined fracture surfaces exhibited features consistent with overstress with no evidence of fatigue damage.

4.1.3. Fuselage Section 44[15] – BS 1035 to 1434

Section 44 remained intact and attached to section 46 and suffered extensive structural damage from BS 1035 to BS 1434. The majority of the passenger windows were missing. There was extensive fire damage from about BS 1035 to BS 1434 from about S-14L to S-14R and from BS 1287 to BS 1434 from S-14R to S-20R. The overhead stow bin support structure (ladder, tie rods, frame attach fittings) was consumed by fire.

4.1.4. Fuselage Section 45[16] – BS 1035 to 1434

The section 45 keel beam web and chord structure under the wing from BS 1035 to BS 1245 were separated from the keel beam and recovered adjacent to the RH side of the airplane. A portion of the keel beam chord remained attached to the center wing lower skin panel. Additionally, a portion of the keel beam structure was recovered about 200 feet to the right of the fuselage. A section 45 keel beam comprised of the butt line (BL) 0 web, the H frames and the keel chords within the wheel well from BS 1245 to BS 1434, was separated from the keel beam and recovered adjacent to the RH side of the airplane under the damaged inboard flap.

The floor support structure from BS 1035 to BS 1434 was undamaged and intact. The LH inboard flap and main landing gear (MLG) beam hanger link support fitting at BS 1371 had a fractured lug. The inboard flap and MLG beam hanger link support fitting at BS 1392 was intact. The hanger link and attach bolts were not attached to these fittings. The forward lug of the hanger link at about BS 1371 was recovered on the runway close to the seawall. The remainder of the hanger link was not recovered. The RH inboard flap and MLG beam hanger link support fittings at BS 1371 and BS 1392 were both intact. The majority of the hanger link remained attached to these fittings. The forward lug of the hanger link at about BS 1371 was recovered on the runway.

All of the observed damage was consistent with ground impact and fire. All of the

[15] reference Attachment 2, Photos 3, 4, 5 & 6
[16] reference Attachment 2, Photos 3, 4, 5 & 6

examined fracture surfaces exhibited features consistent with overstress with no evidence of fatigue damage.

4.1.5. Fuselage Section 46[17] – BS 1434 to 1832

Section 46 had extensive impact damage. Section 46 remained attached to Section 47 at BS 1832. The upper fuselage from about S-20L to S-20R showed little visible external damage. The fuselage below S-20 was displaced inward due to ground impact.

The forward portion of the keel panel from about S-45L to S-45R and about BS 1434 aft to about BS 1643 was torn outboard and to the right and remained inverted adjacent to the RH side of the fuselage. This section of structure included two keel chord extensions which remain attached to the wheel well section 45 keel beam structure. The aft end of the keel panel from about S-27R to about S-45R from about BS 1643 aft to about BS 1832 was torn and displaced to the right of the fuselage, including the small aft cargo door (SACD) cutout. The keel panel from about S-45L to S-45R was missing.

The SACD was recovered about thirty feet aft of the fuselage. The PED 3L cutout edge frames had significant permanent buckling as did the aft edge frame at the PED 3R cutout. All of the windows were intact.

On both sides of the fuselage most of the passenger floor beams to frame attachments were intact. The passenger floor beams within the cross isle of PED 3 were fractured near the side of body and the floor was translated up about 1 foot. This area was directly above the lower lobe crew rest which was observed to have very minor damage and to have displaced the floor upward during ground impact. Most of the passenger floor beam stanchions were not recovered with the airplane but were scattered between the seawall and the airplane. The lower lobe cargo floor beams had extensive damage. The majority were missing along with lower keel beam structure. Only the roller trays located below the cargo containers and crew rest from about BS 1434 to BS 1643 were recovered intact. The remaining lower lobe cargo floor structure was separated and found scattered between the seawall and the airplane.

There was minor fire damage observed between BS 1434 to BS 1476 above S-14. No further fire damage was visible in section 46. The forward portion of the overhead stow bin support structure (ladder, tie rods, frame attach fittings), which is continuous between sections 46 and 47, was intact.

All of the observed damage was consistent with ground impact and fire. All of the examined fracture surfaces exhibited features consistent with overstress with no evidence of fatigue damage.

4.1.6. Fuselage Section 47[18] – BS 1832 to 2150

[17] reference Attachment 2, Photos 6, 13 & 17
[18] reference Attachment 2, Photos 6, 13 & 17

Section 47 had extensive ground impact damage. Section 47 remained attached to section 46. The fuselage from about S-20 and below was displaced inward and damaged due to impact with the ground. There was a circumferential crease from S-20R to S-5L from about BS 1874 to about BS 1895. There were also significant wrinkles from about S-24R to top centerline (TCL) from BS 1832 to BS 1958. The fuselage side skin panel and keel panel from about S-20R to S-45R from about BS 1832 to BS 2150 were also torn outboard and displaced to the right of the fuselage, along with the bulk cargo door cutout. The remainder of the keel panel from about S-45L to S-45R was missing and portions were recovered between the sea wall and the final resting place of the airplane. Portions of BS 2108 and the S-34 frame splices were recovered at the seawall.

Most of the passenger floor beams to frame attachments on the RH side of the aft fuselage were severed with a resultant gap of about one to two feet between the floor beam and frame. Most of the passenger floor beams to frame attachments on the LH side of the fuselage remain attached and intact. Most of the passenger floor beam stanchions in the aft portion were either severed or missing and were recovered along the runway between the seawall and the airplane. A BS 2033 passenger floor stanchion was recovered between the seawall and the threshold. The entire bulk cargo floor was located on the runway close to the seawall. All of the lower lobe cargo floor structure and cargo handling equipment (roller trays, PDUs, etc.) were separated from the airplane, and scattered between the seawall and the airplane.

The PED 4L cutout edge frames were fractured and the adjacent skin was wrinkled. The PED 4L hinge was severed and the door was recovered adjacent to the LH fuselage within about 20 feet. The PED 4L lower sill had impact damage and was severely deformed. All windows were recovered intact. There was little or no fire damage in section 47.

All of the observed damage was consistent with ground impact. All of the examined fracture surfaces exhibited features consistent with overstress with no evidence of fatigue damage.

4.1.7. Fuselage Section 48[19] – BS 2150 to 2570

The structure from BS 2412 to BS 2570 is the auxiliary power unit (APU) compartment. The upper section of the aft pressure bulkhead remained attached to Section 47 and was split vertically near the centerline splice. Portions of the center and lower aft pressure bulkhead were recovered immediately after the seawall and along the runway between the seawall and the airplane. The upper portion of section 48 from about S-20L to S-20R and about BS 2150 to BS 2370, departed the aircraft and was recovered on the runway between the seawall and the threshold marker just left of the runway centerline. The vertical fin remained attached to this portion of section 48, but the pivot bulkhead at BS 2370 was missing. The jackscrew fitting attachments at BS 2245 and BS 2268 were severed and the jackscrew was found attached to the RH horizontal stabilizer. Most of the pivot bulkhead remained attached to the LH horizontal stabilizer and had severe

[19] reference Attachment 2, Photos 18, 19 & 20

impact damage to the lower half of the forward face. The entire LH and RH pivot joints (pivot fittings, pivot backup fittings and pins) remained attached to each respective half of the horizontal stabilizer.

The lower portion of section 48, below S-20, was severely damaged by impact with the seawall and fragments of the structure were recovered in the water adjacent to the seawall, on and in the seawall, and between the seawall and the threshold. Portions of the APU firewall were located between the seawall and the horizontal stabilizer. The partially intact APU compartment, including APU doors was separated from section 48 and found to the right of the runway centerline. The APU firewall was missing from the compartment. The APU itself was found just beyond the APU compartment.

All of the observed damage was consistent with ground impact. All of the examined fracture surfaces exhibited features consistent with overstress with no evidence of fatigue damage.

4.2. Wings

The 777-200 wing[20] is a cantilever, semi-monocoque, cellular structure tapering both in planform and depth. Splices at the side-of-body (body buttock line (BBL) 122.45)[21] join the outboard wing sections to the wing center section.

The outboard wing is comprised of leading edge structure, inspar wing box, and trailing edge structure. The wing box structure consists of the upper and lower skin panels and the front and rear spars with ribs located perpendicular to the rear spar. Major fittings that interface with the outboard wing box include the nacelle support structure, flap support structure and the main landing gear support structure.

The nacelle strut, centered at approximately wing buttock line (WBL) 381, is attached to the inspar wing box via a redundant six point support configuration[22]. The supports consist of the front spar pitch load ("overwing") fitting assembly (R1), the inboard and outboard side load fitting assemblies (R4 and R3 respectively), a two point lower panel fail-safe link fitting (R7 and R8), and the lower panel thrust link fitting assembly (R2).

The main landing gear of the 777-200[23] is supported by the main landing gear beam, and the wing rear spar. The gear attaches to the wing rear spar via a drag brace, near the side-of- body, and a forward trunnion attachment, at approximately wing station (WS) 387. The main landing gear beam, which supports the main landing gear aft trunnion and side brace, is attached to the wing rear spar at approximately WS 490, via the mini-cantilever fitting, and the fuselage at BS 1371, via the hanger link.

The wing center section box runs through the fuselage from left body buttock line

[20] reference Attachment 1, Figures 8,9 & 10
[21] reference Attachment 1, Figure 8
[22] reference Attachment 1, Figure 11
[23] reference Attachment 1, Figure 12

(LBBL) 122.45[24] to right body buttock line (RBBL) 122.45[25] and consists of upper and lower skin panels, front and rear spars, spanwise beams, overwing beams and internal lower beams. The keel beam is attached to the lower panel of the wing center section through fasteners, common to the keel beam upper chord and tension fittings, which are located at the spanwise beam locations.

4.2.1. Right Wing[26]

The right wing was found fully attached to the wing center section. No evidence of damage was observed to the side of body joint. At approximately WS 1250, the wing buckled and was found deflected in the downward direction. The aileron was fractured near the inboard balance tower. The fracture occurred outboard of the wing fuel tanks. Other than the failure of the wing and aileron at about WS 1250 the front and rear wing spars were found intact with no visible damage and the upper and lower inspar wing skins showed no evidence of buckling or wrinkling. There was evidence of localized gouging damage to the wing skins. The damage did not penetrate through thickness of the wing skins. Inboard of the nacelle, at approximately WS 400, a fuel leak was noted emanating from the fuel tank access door. Examination of the area indicated that the door had suffered ground impact damage and one end of the access door was pushed inwards towards the fuel tank. No other visible evidence of fuel tank leakage was noted.

4.2.2. Right Wing - Engine Attachment[27]

The aft upper lug and a short section of the nacelle strut upper link were found intact and attached to the R1 overwing fitting. The upper link was fractured approximately 3" below the upper lug. The R1 front spar pitch load fitting was not significantly damaged.

The R2 thrust link fitting exhibited minor damage due to impact and scraping caused by the separation of the engine thrust link. The severed R2 pin section was found within the lug. Localized scrapes and gouges found on the fitting were consistent with downward fusing of the R2 pin and an outboard engine departure trajectory.

The R4 inboard side load fitting attach pin was fused. The pin fracture surface and damage to the R4 lug was consistent with a downward fusing of the R4 pin.

The R3 outboard side load fitting was found with a missing forward lug. The damage to the lug at the fracture face was consistent with a tension failure.

The R7 and R8 side load link attachment fittings showed only minor damage. The inboard side load links (R7) were not attached to the fitting.

4.2.3. Right Wing – Landing Gear Attachment[28]

[24] reference Attachment 1, Figure 8
[25] reference Attachment 1, Figure 8
[26] reference Attachment 2, Photos 24, 25 & 26
[27] reference Attachment 1, Figure 11

The drag brace fitting and spindle were found intact and remained attached to the rear spar. There were no indications of fuel tank leakage at the rear spar to drag brace fitting interface. The vertical trunnion fittings were intact and the localized gouges, scrapes and surface discolorations were consistent with a downward fusing of the trunnion lower housing. The upper trunnion housing remained attached to the vertical trunnion fittings, also an indication of downwards fusing of the trunnion lower housing. The outboard gear beam fitting remained intact and attached to the rear spar. The gouges and scrapes on the outboard gear beam fitting, and the fracture surfaces of the fused outboard gear beam pins were consistent with a vertical fusing of the outboard of the gear beam. All of the damage to the landing gear support structure was consistent with a vertically-dominated main landing gear overload event.

All of the examined fracture surfaces exhibited features consistent with overstress with no evidence of fatigue damage.

4.2.4. Right Wing - Control and High Lift Surfaces

All of the aerodynamic control and high lift surfaces were found attached to the wing except for the inboard main and aft flaps and spoiler 8. The positions of the attached high lift devices were consistent with flaps 30, the landing position.

The main flap was located aft of the wing and had fractured approximately 4 feet from the inboard end. The inboard end was still attached to the number 5 support, with the support detached from the body. The outboard end of the main flap was still attached to the number 6 support, which was partially detached from the wing.

Spoiler 8 was recovered near the approach end of runway 28L with the right main landing gear and a section of the spoiler beam.

All of the examined fracture surfaces exhibited features consistent with overstress with no evidence of fatigue.

4.2.5. Left Wing[29]

The left wing box was found fully attached to the wing center section. No evidence of damage was found to the side of body joint at LBBL 122.45. The front and rear spars were intact with no visible signs of damage. The upper and lower inspar wing skins showed no evidence of buckling or wrinkling. There was localized gouging and scratching damage to the inspar wing skins due to impact and contact with the ground. None of the damage penetrated through the skin thickness. There was one small puncture to the lower wing skin panel outboard of the surge tank in rib bay 35. Inboard of the nacelle, at approximately WS 400, a fuel leak was noted emanating from a fuel tank access door. No other visible evidence of fuel leakage was noted.

[28] reference Attachment 1, Figure 12
[29] reference Attachment 2, Photos 27 & 28

4.2.6. Left Wing – Engine Attachment[30]

The nacelle strut upper link was found intact and attached to the R1 overwing fitting. The R1 overwing fitting itself exhibited negligible damage. The localized damage and the condition of the forward lug of the upper link indicated that the strut was under a compressive load at the time of fuse pin failure.

The R2 thrust link fitting exhibited only minor damage due to impact and scraping caused by the separation of the engine thrust link. The failed R2 fuse pin section common to the thrust link fitting was contained in the lug and the fracture surfaces of the pin indicated a forward fusing of the pin (i.e. tension in the drag brace).

The R3 and R4 side load fitting attach pins were both fused. Both the R3 and R4 pins and fitting lugs had scoring damage consistent with a forward fusing of the pins. The R3 and R4 fittings had only minor scraping damage near the lugs, associated with the departure of the engine strut after pin fusing.

The R7 and R8 side load link attachment fittings exhibited negligible damage. The side load links were all found attached to the fail safe link fitting.

4.2.7. Left Wing – Landing Gear Attachment[31]

The drag brace fitting and spindle were found intact and remained attached to the rear spar. There were no indications of fuel tank leakage at the rear spar to drag brace fitting interface. The vertical trunnion fittings were intact and the localized gouges, scrapes and surface discolorations were consistent with a downward fusing of the trunnion lower housing. The upper trunnion housing remained attached to the vertical trunnion fittings, also an indication of downwards fusing of the trunnion lower housing. The outboard gear beam fitting remained intact and attached to the rear spar. The gouges and scrapes on the outboard gear beam fitting, and the fracture surfaces of the fused outboard gear beam pins were consistent with a vertical fusing of the outboard of the gear beam. All of the damage to the landing gear support structure was consistent with a vertically-dominated main landing gear overload event.

All of the examined fracture surfaces exhibited features consistent with overstress with no evidence of fatigue.

4.2.8. Left Wing - Control and High Lift Surfaces

Slat 1 was found outboard of the wing tip. The outboard track was still attached to the slat, the inboard track was attached to the wing, with the track attach fitting fractured. The lower surface of the slat was abraded away at an angle consistent with ground scarring witness marks.

[30] reference Attachment 1, Figure 11
[31] reference Attachment 1, Figure 12

Slats 2 and 3 were found under the leading edge of the wing between the side of body and the engine strut attach point. The lower surface of both slats were abraded away similar to slat 1. The slat 3 inboard track was fractured. The remaining slat track attach fittings were fractured at all other locations.

Slats 4 through 7 remained attached to the wing in the flaps 30, landing position. The outboard end of slat 4 had abrasive damage at the outboard end similar to slat 3.

The outboard flap was found in several large sections aft of the wing. One large inboard segment was partially located under the fuselage aft of the wing. Both flap support 1 and 2 were found separated from the wing between the flap sections and the trailing edge. The fuse pins at the under wing fittings were fractured.

The inboard main flap was found between the sea wall and the end of the runway, in two large pieces. The inboard segment of flap was still attached to the Number 4 Support, which fractured at the gear beam extension. The location of the ball screw and drive arm were consistent with the flaps 30 landing position. The outboard half of the aft flap was found in the bay. The inboard end of the aft flap was found in several pieces between the sea wall and the end of the runway. The outboard aft flap track was found below the sea wall in the mud.

The aileron was fractured into multiple pieces and located aft of the wing. A small segment remained attached to the actuators on the wing.

The flaperon remained attached to the wing with significant damage.

The outboard spoilers remained attached to the wing. The inboard spoilers were found between the sea wall and the end of the runway still attached to the spoiler beam.

All of the examined fracture surfaces exhibited features consistent with overstress with no evidence of fatigue.

4.2.9. Wing Center Section

Examination of the external wing center section revealed no signs of significant structural damage. The upper wing section skin panels were observed by removing the selected floor panels over the wing center section and by cutting inspection holes in the floor panels in areas where panel removal was not practical or safe. No damage was observed in the inspected areas of the wing upper surface or in the overwing floor beams. The front and rear spars were intact with no visible signs of fuel leakage. The lower panel was damaged during the ground slide, but the damage was limited to superficial skin gouging and scratching. The keel beam web and lower chord was found separated from the wing center section lower skin panel and came to rest along the right hand side of the airplane. Failure of the keel beam occurred in the beam web and the upper keel beam chord flanges remained attached to the wing lower surface. There was

no evidence of fuel leakage from the wing center section and there were no indications of fire or soot along the wing center section front or rear spars.

All of the examined fracture surfaces exhibited features consistent with overstress with no evidence of fatigue.

4.3. Vertical Stabilizer Description[32]

The vertical stabilizer main torque box is primarily a graphite epoxy laminate construction (skin/stringer, spars, ribs). The leading edge and trailing edge structure is aluminum and fiberglass construction. The rudder is constructed of graphite epoxy honeycomb sandwich material. The fin is attached to section 48 through 8 titanium tension fittings and 16 tension bolts.

4.3.1. Vertical Stabilizer Damage[33]

The fin root attachment, including tension bolts, showed no visible signs of damage. The fin to body fairing structure is severely deformed, consistent with a forward rocking motion of the fin. The vertical stabilizer leading edge dorsal has impact damage at multiple locations. The most severe damage is a leading penetration to the auxiliary torque box spar near the fin root at about fin station (FS) 150. The damage has witness marks consistent with a tire impact. At about the same fin station the LH skin panel has a penetration and witness marks consistent with a tire impact. The tire witness marks extend onto the adjacent section 48 crown skin. Another significant damage site with a leading edge penetration thru to the auxiliary torque box spar was located on the upper half of the stabilizer at about fin station 400.

The rudder remained attached to the vertical fin with minor damage to the rudder trailing edge and skin fractures where the caused by the separation of the balance weight. The balance weight was located about 300 feet north of the vertical fin and to the right of the runway 28L in the grassy area between the seawall and taxiway C, between runways 28L and 28R.

All of the observed damage was consistent with ground impact. All of the examined fracture surfaces exhibited features consistent with overstress with no evidence of fatigue damage.

4.4. Horizontal Stabilizer Description[34]

The horizontal stabilizer is a two piece construction with a centerline splice. The main torque box is primarily a graphite epoxy laminate construction (skin/stringer, spars, ribs). The leading edge and trailing edge structure is an aluminum and fiberglass construction. It has two aft pivot fittings and one forward jackscrew fitting. The LH and

[32] reference Attachment 1, Figures 15 & 16
[33] reference Attachment 2, Photos 20 & 23
[34] reference Attachment 1, Figures 13 & 14

RH elevators are constructed of graphite epoxy honeycomb sandwich material.

4.4.1. Left Stabilizer Damage[35]

The LH stabilizer leading edge bull nose had impact damage at several locations. The horizontal stabilizer fractured to the left of the butt line (BL) 0. The BL0 splice plates remained attached to the RH stabilizer. The LH pivot fitting was still attached to the section 48 structure (the section 48 pivot fittings, bulkhead web and backup fittings) by the pivot pins. The fracture occurred in the graphite epoxy skins and spars away from the BL0 splice. The most severe was a softball sized penetration to the auxiliary torque box spar caused by a rock. The outboard 3 feet of the elevator fractured from the main body of the elevator and was located adjacent to the stabilizer and elevator. The remainder of the elevator was attached to the horizontal stabilizer with minimal structural damage.

All of the observed damage was consistent with ground impact. All of the examined fracture surfaces exhibited features consistent with overstress with no evidence of fatigue damage.

4.4.2. Right Stabilizer Damage[36]

The RH stabilizer leading edge bull nose had impact damage at several locations. The horizontal stabilizer fractured to the left of the BL0 splice. The fracture to the stabilizers occurred in the graphite epoxy skins and spars to the left of the BL0 splice. The splice plates, front and rear spar terminal fittings, BL0 rib, jack screw and jack screw fittings remained attached to the RH stabilizer structure. The forwardmost one foot segment of the lower BL0 splice plate fractured and was embedded in the runway between the seawall and the horizontal stabilizers. The LH and RH front spars, spar terminal fittings and jackscrew fittings were fractured at the spar lower chords. The chords were deformed in a vertical direction consistent with a vertical load at impact. The lower non load bearing section of the jackscrew that extends below the ball nut was separated from the upper load bearing section still connecting the ball nut and upper gimbal. This lower portion was located about 50 feet beyond the stabilizers. The RH pivot fitting was still attached to the section 48 structure (section 48 pivot fittings, bulkhead web and backup fittings) by the pivot pins.

4.5. Doors

There are eight type (A) Passenger Entry Doors (PED). They are plug type doors that are inward and outward acting and react only cabin pressure loads. The doors consist of an outer skin, horizontal beams, vertical frames, vertical intercostals and inner skin at selected locations and stop fittings on the forward and aft edges.

The large forward cargo door (LFCD) is an outward opening door on the RH side of

[35] reference Attachment 2, Photo 21
[36] reference Attachment 2, Photo 22

section 41. It is a shear type door, carrying fuselage shear and cabin pressure loads. It consists of vertical frames, an outer skin, partial inner skin, and intercostals. The door is supported by an upper piano hinge and rotary latches at the lower sill.

The small aft cargo door (SACD) is an outward opening door on the RH side of section 46. It is a plug type door, carrying only cabin pressure. The door consists of an outer skin, horizontal beams, vertical frames, vertical intercostals, inner skin at selected locations and stop fittings on the forward and aft edges.

The bulk cargo door is an inward opening door on the RH side of section 47 which is a plug type door that reacts only cabin pressure loads. The doors consist of an outer skin, horizontal beams, vertical frames, vertical intercostals, and an inner skin at selected locations. The door is supported by upper hinge fittings and latch probes on the forward and aft edges

4.5.1. Passenger Entry Door (PED) 1L[37]

PED 1L remained attached to the airplane and had no visible signs of damage.

4.5.2. PED 1R[38]

PED 1R remained attached to the airplane and had no visible signs of damage.

4.5.3. PED 2L[39]

PED 2L remained attached to the airplane and had no visible signs of damage.

4.5.4. PED 2R[40]

The interior surface of PED 2R had no visible signs of fire damage. PED 2R had extensive fire damage on the exterior skin with partial burn through which was just above the area where the No. 2 engine came to rest.

4.5.5. PED 3L[41]

PED 3L remained attached to the airplane and had no visible signs of damage. Refer to section 46 discussions for edge frame damage.

4.5.6. PED 3R[42]

PED 3R remained attached to the airplane and had no visible signs of damage. Refer to

[37] reference Attachment 2, Photo 7
[38] reference Attachment 2, Photo 8
[39] reference Attachment 2, Photo 9
[40] reference Attachment 2, Photo 10
[41] reference Attachment 2, Photo 11
[42] reference Attachment 2, Photo 14

section 46 discussions for edge frame damage.

4.5.7. PED 4L[43]

PED 4L separated from the airplane and had no visible signs of damage other than the severed hinge joint and minor abrasions and dents consistent with ground contact. However, the forward edge frame was fractured between door stops 5 and 6. This was the only PED that separated from the airplane and was located adjacent to and within about 20 feet of the LH side of the fuselage. Refer to section 47 discussions for edge frame damage.

4.5.8. PED 4R[44]

PED 4R remained attached to the airplane and had no visible signs of damage. Refer to section 47 discussions for edge frame damage.

4.5.9. LFCD

The LFCD remained attached to the airplane and had no visible signs of damage.

4.5.10. SACD[45]

The SACD separated from the airplane and had significant damage consistent with ground impact. The door was found aft of the aft pressure bulkhead and within about 30 feet of the fuselage. Refer to section 46 discussion for SACD cutout damage.

4.5.11. Bulk Cargo Door

The bulk cargo door remained attached to the fuselage at the upper hinge and had significant damage consistent with ground impact. Refer to section 47 discussion for bulk cargo door cutout damage.

4.6. Landing Gear

The 777 has three landing gears consisting of a forward nose gear and two main gears. The two main gears are located in the trailing edge area of the outboard wings.

The 777-200 main landing gear is a 6-wheeled tripod gear, supported by a trunnion (located at the top of the gear post), a drag brace and a side brace. The drag brace is connected to the rear spar near the side-of-body, and the side brace is connected to the fuselage at the inboard end of the landing gear beam.

The forward trunnion attaches to the wing box by means of two trunnion housings and

[43] reference Attachment 2, Photo 16
[44] reference Attachment 2, Photo 17
[45] reference Attachment 2, Photo 15

two vertical trunnion housing support fittings. The fittings are attached to the rear spar and the upper and lower wing skin tabs, which protrude aft of the rear spar. The aft trunnion is supported by the landing gear beam. The inboard end of the gear beam is connected to the fuselage structure by the hanger link assembly, which allows rotation about an axis perpendicular to the landing gear beam, preventing the landing gear beam from resisting wing bending loads. At the outboard end, the gear beam is supported by a mini-cantilever fitting attached to the rear spar and to the upper and lower wing skin overhang, specifically tabbed out for this attachment.

The 777-200 nose gear is a two-wheeled, single chambered shock strut gear. It is connected to the fuselage at four points; two drag brace trunnions and two outer cylinder trunnions.

4.6.1. Nose Gear & Support Structure

The nose landing gear remained attached to the airplane at all four trunnion locations. The outer cylinder fractured just above the side and drag braces. The separated lower portion of the nose gear was located adjacent to the right hand side of section 41. Both the wheels and tires separated had from the nose landing gear. The right wheel and tire were found assembled and located about 100 feet forward of the nose of the airplane. The left wheel and tire were severely damaged and located near the runway threshold between the seawall and the airplane. The left end of the axle was partially fractured and the right end of the axle was intact.

All of the examined fracture surfaces exhibited features consistent with overstress with no evidence of fatigue.

4.6.2. Right Main Gear & Support Structure[46]

The forward face of the hanger link fitting was found past the displaced threshold, on the right hand side of the runway. The hanger link pin was found forward of the hangar link fitting piece, forward of the runway threshold. The remainder of the hanger link fitting remained attached to the airplane. The main landing gear departed the airplane and was found in three major sections. The forward axle and wheels and a portion of truck beam were on the left hand side of the runway, approximately 100 feet past the runway threshold. The inboard aft wheel and tire were found just forward of the forward axle along with the trunnion lower housing. The gear post, remaining truck beam, gear braces, aft outboard wheel and tire and center axle/wheels/tires were found together, near the runway indicator markings, on the right side of the runway. The main landing gear beam was found off to the right side of the runway, about 1000 feet down the runway from the threshold.

The inboard end of the landing gear beam was fractured inboard of its connection to the hanger link. A portion of the gear beam inboard end remained attached to the end of the side brace. The outboard end of the gear beam was fused at the outboard gear beam

[46] reference Attachment 1, Figures 12

support fitting. The drag brace was fractured near the lug connecting it to the rear spar drag brace fitting.

The inboard forward and aft tires each exhibited large sidewall failures. The trunnion lower housing was found separated from the vertical trunnion fittings and the rear spar, with all 4 pins fused. The damage to the left hand landing gear was consistent with a vertically-dominated main landing gear overload event.

All of the examined fracture surfaces exhibited features consistent with overstress with no evidence of fatigue.

4.6.3. Left Main Gear & Support Structure[47]

The forward face of the hanger link fitting and the hanger link pin were found short of the displaced threshold. The remainder of the hanger link fitting was not recovered. The main landing gear separated from the airplane into three major pieces. The outboard center wheel and tire were found on the left hand side of the runway approximately 100 feet past the displaced threshold. The forward axle, wheels and tires along with a portion of truck beam were located on the right hand side of the runway, approximately100 feet past the displaced threshold. The gear post, remaining truck beam, gear braces, center inboard wheel and aft axle, wheels and tires and the remaining truck beam were found together short of and to the right side of the runway threshold. The trunnion lower housing was also found in this area, with all 4 of the pins fused.

The inboard end of the gear beam was fractured at the connection to the gear beam extension. The outboard end of the gear beam was fused at outboard gear beam support fitting. The drag brace was found fractured near the lug connecting it to the rear spar drag brace fitting. The side brace remained attached to the inboard end of the landing gear beam.

Taken in whole, the damage to the left hand landing gear was consistent with a vertically-dominated main landing gear overload event.

All of the examined fracture surfaces exhibited features consistent with overstress with no evidence of fatigue.

[47] reference Attachment 1, Figures 15 & 16

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